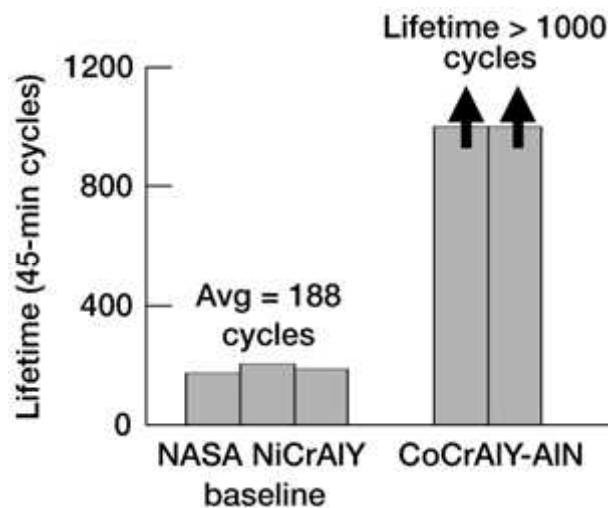
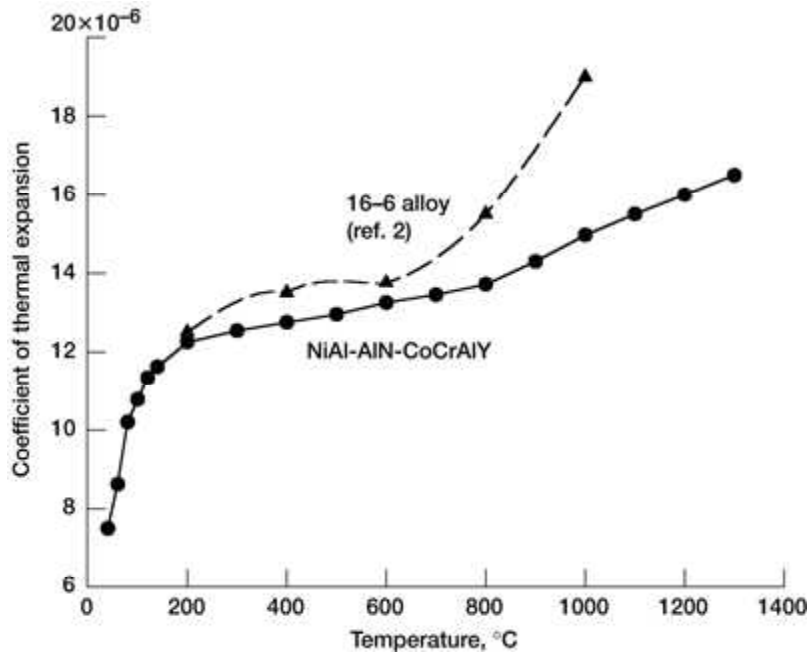


# High-Temperature Oxidation-Resistant and Low Coefficient of Thermal Expansion NiAl-Base Bond Coat Developed for a Turbine Blade Application

Many critical gas turbine engine components are currently made from Ni-base superalloys that are coated with a thermal barrier coating (TBC). The TBC consists of a  $\text{ZrO}_2$ -based top coat and a bond coat that is used to enhance the bonding between the superalloy substrate and the top coat. MCrAlY alloys (CoCrAlY and NiCrAlY) are currently used as bond coats and are chosen for their very good oxidation resistance. TBC life is frequently limited by the oxidation resistance of the bond coat, along with a thermal expansion mismatch between the metallic bond coat and the ceramic top coat.

The aim of this investigation at the NASA Glenn Research Center was to develop a new longer life, higher temperature bond coat by improving both the oxidation resistance and the thermal expansion characteristics of the bond coat. Nickel aluminide (NiAl) has excellent high-temperature oxidation resistance and can sustain a protective  $\text{Al}_2\text{O}_3$  scale to longer times and higher temperatures in comparison to MCrAlY alloys. Cryomilling of NiAl results in aluminum nitride (AlN) formation that reduces the coefficient of thermal expansion (CTE) of the alloy and enhances creep strength. Thus, additions of cryomilled NiAl-AlN to CoCrAlY were examined as a potential bond coat. In this work, the composite alloy was investigated as a standalone substrate to demonstrate its feasibility prior to actual use as a coating.

About 85 percent of prealloyed NiAl and 15 percent of standard commercial CoCrAlY alloys were mixed and cryomilled in an attritor with stainless steel balls used as grinding media. The milling was carried out in the presence of liquid nitrogen (ref. 1). The milled powder was consolidated by hot extrusion or by hot isostatic pressing. From the consolidated material, oxidation coupons, four-point bend, CTE, and tensile specimens were machined. The CTE measurements were made between room temperature and 1000 °C in an argon atmosphere. The top figure shows that the CTE of the NiAl-AlN-CoCrAlY composite bond coat is lower than that of the commercially used coating alloy 16-6.



*Top: The coefficient of thermal expansion of NiAl is significantly reduced by the presence of nanosized aluminum nitride and cobalt-chromium-aluminum-yttrium particles. The CTE mismatch between the NiAl-AlN-CoCrAlY bond coat and top ceramic coat is reduced in comparison to that of a ceramic top coat and 16-6 bond coat. Hence, this NiAl-AlNCoCrAlY bond coat exhibits superior life time as shown in the bottom graph.*

*Top: CTE of NiAl-AlN-CoCrAlY compared with that of a Ni-base bond coat (16-6 alloy).  
Bottom: TBC lifetime of NiAl-AlN-CoCrAlY compared with that of the NASA NiCrAlY baseline alloy.*

To examine the potential of NiAl-AlN-CoCrAlY as a bond coat, we subjected two samples to cyclic furnace testing. The furnace cycle consisted of 45 min at 1163 °C (2125

°F ) followed by 15 min of cooling out of the furnace. The current NASA baseline TBC is a NiCrAlY bond coat below the 7YSZ top coat. The average TBC life for this baseline coating on René N5 is  $188 \pm 19$  cycles as shown in the bottom figure. NiAl-AlN-CoCrAlY specimens coated with the same 7YSZ top coat were still intact even after 1000 cycles.

Therefore, the NiAl-AlN-CoCrAlY as a bulk substrate material, exhibits more than 5 times the life of the current state-of-the-art material. The next step is to evaluate this material as a coating on the same superalloy substrate.

**Find out more about this research at the Materials Division Web site**  
**<http://www.grc.nasa.gov/WWW/MDWeb/>.**

## **References**

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